as regards his facts. He appears to have overlooked the observations proving the *lower* salinity of inter-tropical water, which I had cited as furnishing an additional indication that Polar water is constantly rising from the bottom towards the surface in the equatorial area. These observations have been most remarkably confirmed by those taken by the physicists of the *Challenger*. For, whilst in the extra-tropical area the sp. gr. of surface-water was in excess of that of bottom-water, in the equatorial area it was reduced to an almost precise correspondence with it, due allowance for temperature being of course made.

According to Mr. Croll's doctrine, the whole of that vast mass of water in the North Atlantic, averaging, say, 1,500 fathoms in thickness, and 3,600 miles in breadth, the temperature of which (from 40° downwards) as ascertained by the *Challenger* soundings, clearly shows it to be mainly derived from a Polar source, is nothing else than *the reflux of the Gulf Stream*. Now, even if we suppose that the whole of this stream, as it passes Sandy Hook, were to go on into the closed Arctic Basin, it would only force out an equivalent body of water. And as, on comparing the sectional areas of the two, I find that of the Gulf Stream to be about 1-900th that of the North Atlantic underflow; and as it is admitted that a large part of the Gulf Stream returns into the Mid-Atlantic circulation, only a branch of it going on to the north-east; the extreme improbability (may I not say impossibility?) that so vast a mass of water can be put in motion by what is by comparison such a mere rivulet—the north-east motion of which, as a distinct current, has not been traced eastward of 30° W. long.—seems still more obvious.

Lastly, the *Challenger* observations in the South Atlantic have proved exactly what I had anticipated, viz., that the bottom-temperature is lower, and that the Polar underflow lies much nearer the surface in this ocean than in the North Atlantic. Now this case appears to me to afford the *experimentum crucis* between Mr. Croll's doctrine and my own. For my prediction of this result was based on the fact, that, as there is here a perfectly open communication between the Polar and equatorial areas, the vertical circulation would take place more freely. On the other hand, according to Mr. Croll's doctrine, it would have been expected that there should be a far smaller reflux, or no reflux at all. For, though a portion of the equatorial current passes southwards when it meets the coast of South America, there is no ground whatever for believing that it ever goes near the Antarctic circle; and if it did find its way thither, there is no "closed basin" from which it can drive back a return current.

As it is usually considered in scientific inquiry that the verification of a prediction affords cogent evidence of the validity of the hypothesis on which it is based, I venture to submit that so far my case has been made good.

WILLIAM B. CARPENTER

THE DEATH OF DR. LIVINGSTONE

THE daily papers have obtained from the London office of the *New York Herald* the following telegram, containing details of the death of Dr. Livingstone, dated Suez, Sunday, March 29:—

"The *Malwa* arrived off Suez at eleven on Saturday night, having Mr. Arthur Laing and Jacob Wainwright on board, with the body of Livingstone. He had been ill with chronic dysentery for several months past. Although well supplied with stores and medicine, he seems to have had a presentiment that the attack would prove fatal. He rode a donkey, but was subsequently carried, and thus arrived at Muilala, beyond Lake Bemba, in Bisa country, when he said, 'Build me a hut to die in.' The hut was built by his followers, who first made him a bed. He suffered greatly, groaning night and day. On the third day he said, 'I am very cold; put more grass over the hut.' His followers did not speak or go near him. Kitumbo, Chief of Bisa, sent flour and beans, and behaved well to the party. On the fourth day Livingstone became insensible, and died about midnight. Majuahra, his servant, was present. His last entry in diary was on April 27. He spoke much and sadly of home and family. When first seized he told his followers he intended to change everything for ivory, to give to them, and to push on to Ujiji and Zanzibar, and try to reach England. On the day of his death the followers consulted what to do. The Nassick boys determined to preserve the remains. They were afraid to inform the Chief of Livingstone's death. The secretary removed the body to another hut, around which he built a high fence to ensure privacy. They opened the body and removed the internals, which were placed in a tin box and burned inside the fence under a large tree. Jacob Wainwright cut an inscription on the tree as follows:—'Dr. Livingstone died on May 4, 1873,' and superscribed the name of the head man Susa. The body was preserved in salt, and dried in the sun for twelve days. Kitumbo was then informed of the death, and beat drums and fired guns as a token of respect, and allowed the followers to remove the body, which was placed in a coffin formed of bark, then journeyed to Unyanyembe about six months, sending an advanced party with information addressed to Livingstone's son, which met Cameron. The latter sent back a bale of cloth and powder. The body arrived at Unyanyembe ten days after advanced party, and rested there a fortnight. Cameron, Murphy, and Dillon together there. Latter very ill, blind, and mind affected. Committed suicide at Kasakera; buried there. Here Livingstone's remains were put in another bark case, smaller, done up as a bale to deceive natives who objected to the passage of the corpse, which was thus carried to Zanzibar. Livingstone's clothing, papers, and instruments accompany the body. When ill Livingstone prayed much. At Muilala he said, 'I am going home.' Chumah remains at Zanzibar. Webb, American consul at Zanzibar, is on his way home, and has letters handed to him by Murphy from Livingstone for Stanley, which he will deliver personally only. Geographical news follows. After Stanley's departure the Doctor left Unyanyembe, rounded the south end of Lake Tanganyika, and travelled south of Lake Bemba, or Bangneoleo, crossed it south to north, then along east side, returning north through marshes to Muilala. All papers sealed. Address Secretary of State, in charge of Arthur Laing, a British merchant from Zanzibar. Murphy and Cameron remain behind."

These details are few but intensely touching. We believe that the Peninsular and Oriental Company's Bombay steamer *Malwa*, with Dr. Livingstone's body on board, is due on April 13 at Southampton. The body will be landed at that port and conveyed to London, by railway, for interment in Westminster Abbey; it is to be regretted that the faithful Chumah does not accompany his master's remains. It is impossible that Government will fail in doing what the whole civilised world takes for granted it will do—pay all possible honour to the remains of H. M. Consul, and of probably the greatest traveller that this or any other country ever produced.

REPORT OF PROF. PARKER'S HUNTERIAN LECTURES "ON THE STRUCTURE AND DEVELOPMENT OF THE VERTEBRATE SKULL"

THE new Hunterian Professor, Mr. W. Kitchen Parker, has just completed his course of eighteen lectures at the College of Surgeons, embodying in them the results of his researches on that most difficult problem, the development of the vertebrate skull. The plan pursued by Mr. Parker has been to describe first in their adult state, and afterwards in the various stages of their development, the skulls of certain prominent vertebrates which should serve as types for the other members of the group, and to deduce from the facts thus established the principles on which the cranium is constructed in the whole sub-kingdom. The types selected were the shark, skate, salmon, axolotl, frog, snake, fowl, and pig.

I.—*Morphological Elements of the Skull.* Nothing can be more hopeless than the attempt to unravel and explain the vertebrate skull by the study of adult forms only. The modification of face and brain-case, in the long line of creatures which begins with the lamprey and ends with man, are so endless that, until the study of embryology put the matter on a new and firm foundation, the best observers failed signally to produce a true "theory of the skull," the most elaborate attempt of the kind—the "vertebral theory" started by Goethe and Oken in Germany, and perfected by Prof. Owen in England—having resulted only in a convenient working hypothesis.

When, however, instead of starting with the highly differentiated skulls of adult animals, the embryos of these animals from their earliest conditions are made the subject of investigation, a new light is shed on the whole question. It is found that the skulls of all the vertebrata which have yet been thoroughly worked out, originate in, practically, a precisely similar manner; and even in some of the more advanced stages it would be hard to point out very essential differences between the skulls of a fish, a bird, or a mammal. Before entering upon the description of the skull of the shark, the first type to be gone into,* it will be advisable to consider the distinct elements of which the *primordial cranium* of any vertebrate animal is made up.

a. On either side of the anterior termination of the notochord, or primitive axis of the body (Fig. 1, Ch.), is developed a cartilaginous plate (I.M), which as a rule unites both above and below the notochord with its fellow of the opposite side. These plates taken together were termed by Rathke the *investing mass:* in the language of Prof. Huxley, they constitute the *parachordal elements* of the primordial skull or *chondro-cranium.*

b. In front of and below the investing mass, cartilaginous thickenings with intervening spaces are developed in the side walls of the body, enclosing, rib-like, the pharyngeal cavity. These are the *visceral arches* (pleural elements, Huxley), the spaces between them the visceral clefts. The usual number of these bars is eight, although in certain exceptional cases they may be increased to nine (Hexanchus) or ten (Heptanchus). Taken from before backwards, the pleural arches are named as follows:—1. trabecular (Tr), 2. mandibular (Mn), 3. hyoid (Hy), 4-8. branchial (Br. 1—5), the clefts separating them being in like manner, the mouth (M), the tympano-Eustachian passage (Ty Eu) and the branchial clefts (Cl 1—5). At a very early period, the mandibular arch gives off a forward process, the palato-pterygoid arcade (Pl Pt) which in certain cases takes on the form of a distinct pleural element. In the branchiate vertebrata (Fishes and Amphibia) all these arches with the single exception of the trabecular may bear functional gills, the presence of these organs being the chief physiological test of their serial homology.

FIG. I.

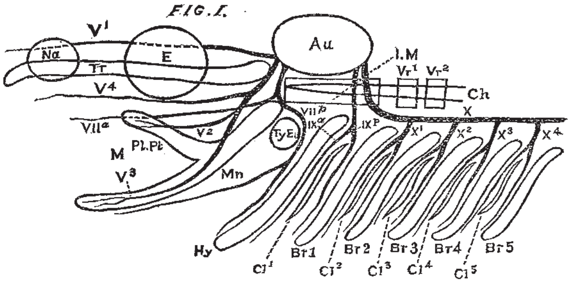

FIG. 1.—DIAGRAM OF VERTEBRATE SKULL. Ch, Notochord; Vr¹, Vr², first and second vertebræ; I.M, investing mass; Au, auditory capsule; E, eye; Na, nasal capsule; Tr, trabecular; Mn, mandibular; Hy, hyoid; Br.1-5, branchial arches; Pl.Pt, pterygo-palatine process; M, mouth; Ty.Eu, tympano-Eustachian passage: Cl.1-5, branchial clefts; V¹. orbito-nasal; V², maxillary; V³, mandibular; V⁴, palatine division of the trigeminal nerve; VII^a, vidian; VII^p, hyomandibular divisions of portiodura; IX, glossopharyngeal; X, vagus.

FIG. 2

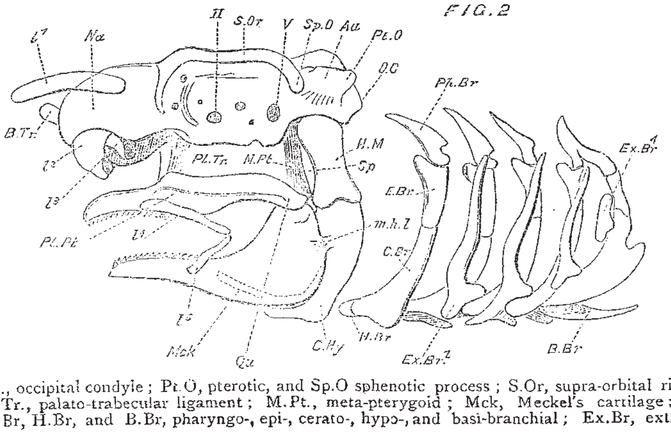

FIG. 2.—SKULL OF SHARK. O.C., occipital condyle; Pt.O, pterotic, and Sp.O sphenotic process; S.Or, supra-orbital ridge; B.Tr, basi-trabecular l^1, l^2, l^3, l^4, l^5, labial cartilages; Pl.Tr., palato-trabecular ligament; M.Pt., meta-pterygoid; Mck, Meckel's cartilage; H.M, hyo-mandibular; C.Hy, cerato-hyal: Ph.Br, E.Br, C.Br, H.Br, and B.Br, pharyngo-, epi-, cerato-, hypo-, and basi-branchial; Ex.Br, extra-branchials; Sp, spiracle; II, Optic foramen.

Far more important, however, in the determination of these elements of the skull, are the morphological landmarks afforded by the cranial nerves, especially by the 5th, 7th, 9th, and 10th pairs. It is the constant habit of these nerves to fork above a visceral cleft, one of the branches thus formed supplying the posterior face of the arch in front of the cleft, the other the anterior face of the arch behind and (see Fig. 1). The orbito-nasal or ophthalmic (V¹) and the palatine (V⁴) divisions of the trigeminal are the special trabecular nerves, the former passing over the optic nerve, the latter below it. The posterior primary subdivision of this nerve passes behind the mouth-cleft, and divides into two branches, both of which are distributed to the anterior (or in the altered position of the three foremost arches, outer) side of the mandibular arch; the mandibular, or inferior maxillary nerve (V³) passing along the original direction of the arch, the superior maxillary (V²) following the pterygo-palatine process. The seventh nerve, or portiodura, divides above the tympano-Eustachian passage, its anterior branch (VII^a) going to the inner (posterior) side of the mandibular arch, and its posterior (VII^p) division to the outer side of the hyoid. The glossopharyngeal (IX.), in like manner, is distributed to the inner side of the hyoid and the front face of the first branchial, the hinder face of which, as well as all the remaining branchial arches, is supplied by the great tenth nerve, or vagus (X).

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* The development of the skull in the Marsipobranchii (Lamprey and Hag), the lowest group of craniate Vertebrata, has not yet been studied with sufficient accuracy to allow of the determination of its parts with any degree of certainty.

By Rathke, to whom are due the first accurate observations on the development of the skull, the trabecular arches were looked upon as mere forward processes of the investing mass, and were called *trabeculæ cranii*, or "rafters of the skull." This misconception of their true nature arose from the fact that they very soon coalesce with the investing mass, and are only to be found distinct in extremely early stages.

c. Round the organs of smell and hearing cartilaginous investments are formed, known respectively as the nasal (Na) and auditory (Au) capsules. The latter become, at a very early period, united with the investing mass, while the nasal capsules come into close relations with the anterior or distal ends of the trabeculæ.* These are the *paraneural elements* of the primordial skull.

d. Certain cartilages may be developed in relation with and external to the visceral arches, called from this circumstance "extra-viscerals." Of this nature are the labial cartilages, which take so large a share in the formation of the skull of many cartilaginous fishes.

e. Lastly, the general membranous roof and walls of the brain-case may chondrify to a greater or less extent, but this chondrification is in nearly every case continuous with the trabeculæ and nasal capsules in front and below, and with the investing mass and auditory capsules behind.

Not only is the originally membranous cranium thus strengthened by deposits of cartilage, but osseous deposits may take place either in the primordial skull itself, or in the subcutaneous tissue surrounding it. The latter are called "investing-bones," or *parostoses;* the former may be of two kinds; when occurring as mere calcifications of the substance of the cartilage, they are known as *endostoses*, when having the structure of true bone, as *ectostoses*.

II.—*Skull of the Shark* (*Lesser Spotted Dog-fish*, Scyllium canicula).—The skull of the shark is one of the best examples of the chondro-cranium in its least altered state, being entirely uncomplicated by the development of investing bones, and covered simply by a close-set series of superficial calcifications.

The brain-case is much flattened both above and below. Seen from above, it is greatly excavated in its central portion by the orbits, but expanded in front by the rounded nasal capsules (Fig. 2, Na), and behind by the more or less quadrate auditory capsules (Au). The cartilaginous roof of the skull, or *tegmen cranii*, is interrupted by an oval membranous space, or "fontanelle," situated between the hinder boundaries of the nasal sacs, a position peculiar to the sharks. The upper surface of the otic capsules exhibits three well-marked elevations for the semi-circular canals, and just within that for the anterior canal, a small rounded aperture, the remains of the primitive involution of the integument from which the organ of hearing arose. An elevation on the hinder end of the posterior canal marks the position of the epiotic ossification so well developed in the osseous fish; the pterotic is also indicated by a large outstanding process (Pt O) which forms the postero-external angle of the skull, and the sphenotic (post-frontal of Cuvier) by the posterior portion of the supra-orbital ridge (S Or) when it coalesces with the auditory capsule (Sp O). The anterior extremity of this ridge forms in like manner the pre-frontal process. One very noteworthy point, observable both in an upper, under, or side view, is the presence between the nasal capsules of a short rod of cartilage (B Tr) representing the median basal portion, or keystone of the trabecular arch, and hence called the basi-trabecular.

Viewed from behind, the skull presents a large foramen magnum, bounded below and at the sides by the well-developed occipital condyles, between which is a slight elevation, showing the point where the notochord originally entered the investing mass. External to the occipital foramen, and marking the original boundary between the parachordal and otic elements of the skull is the foramen for the exit of the 9th and 10th nerves. The trigeminal foramen, which always points to the anterior limit of the otic region, forms a large aperture in the side wall of the brain-case (V), as also does the optic foramen (II).

The jaws are very loosely united to the other parts of the skull, and consist of an upper and a lower dentigerous arch, the former of which is connected with the skull by two bands of ligamentous fibres. The lower arch (Mck), which articulates with the posterior end of the upper, is the homologue of Meckel's cartilage, the rod which forms the foundation of the lower jaw in all vertebrata, but which as a rule, owing to the great development of investing bases, is reduced to a more slender style, or is even suppressed altogether. The posterior portion of the upper dentigerous arch (Qu) answers to the quadrate, a bone which in all Teleostei, as well as in Amphibia and Sauropsida, gives attachment to the mandible. The remainder of this "upper-jaw" represents the series of bones (pterygoid, meso-pterygoid, and palatine) which in the osseous fish connect the quadrate with the fore-part of the skull, the meta-pterygoid or proximal end of the mandibular arch being represented by the band of fibrous tissue (M Pt) which connects the quadrate with the auditory capsule.

Close behind the attachment of the meta-pterygoid ligament, a large phalangiform cartilage (H M) is articulated to the auditory capsule; this represents the hyomandibular of the osseous fish, the largest bone in the suspensory apparatus of the lower jaw, and the uppermost portion of the hyoid arch. Between this cartilage and the meta-pterygoid is a space (Sp), which in the recent state forms a communication between the cavity of the mouth and the exterior. This is called the spiracle, and answers to the tympano-Eustachian passage of the higher vertebrata. The distal portion of the hyoid arch consists of a large and strong cartilage, the cerato-hyal (C Hy), below which is a basal piece, common to both sides (shown in the figure by dotted lines), the basi-hyal. This is an extremely simple mode of segmentation of the hyoid arch, and approaches nearly to the primitive condition.

The cerato-hyal is connected with the mandible by a ligament—the mandibulo-hyoid ligament (mhl).

There are five branchial arches, all of which are split up into four segments, called, after the names originally given by Prof. Owen to the corresponding parts in the Teleostei, pharyngo- epi-, cerato-, and hypo-branchial. The inferior median piece, or basi-branchial (B Br), occurs only in the hinder part of the series.

The extra-viscerals are represented by the labial cartilages (l^1—l^5) and by the extra-branchials (Ex Br 1—5), between which and the branchial arches extend cartilaginous rods, acting as supports to the septa between the gill-pouches. The last arch, however, bears no gill and has no extra-branchial corresponding to it. The hyoid also is devoid of an extra-visceral, although it bears a series of greatly divided cartilages, which support the anterior wall of the first gill-sac; this arch, consequently, carries a half-gill. The branchia of the mandibular arch is represented by a vascular plexus (pseudo-branchia) on the anterior side of the spiracular opening.

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* The Sclerotic, the fibrous (mammalia), or cartilaginous (Sauropsida and Ichthyopsida) capsule developed around the organ of sight (E) never really forms part of the skull, although in the sharks and rays, and some osseous fish, it is articulated with the side walls of the brain case by a cartilaginous pedicle. The form of the skull is, however, greatly governed by the presence of these optic capsules.